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Research article

Aerobic fitness and game performance indicators in professional football players; playing position specifics and associations

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ABSTRACT

The aim of this study was to identify associations between aerobic fitness (AF) and game performance indicator (GPI) in elite football. Participants were professional football players (males, $n = 16$; age: 23.76 ± 2.64; body height: 181.62 ± 7.09 cm; body mass: 77.01 ± 6.34 kg). AF testing was conducted by direct measurement and included VO2max, running speed at aerobic threshold (AeT), and running speed at anaerobic threshold (AT). The GPI were collected by the position-specific performance statistics index (InStat index). The players were observed over one competitive half-season, resulting in 82 game performances, grouped according to the positions in game: defenders ($n = 39$), midfielders ($n = 32$) and forwards ($n = 11$). VO2max was not found to be a good discriminator of AF among different playing positions. AeT (F-test = 26.36. $p = 0.01$) and AT (F-test = 7.25, $p = 0.01$) were highest among midfielders, and lowest among forwards. No correlations were found between AF and GPI. This study confirmed that AeT and AT are better indicators of AF than VO2max in football players at different playing positions. The lack of associations between AF and GPI was discussed with regard to calculation of InStat as a GPI.

1. Introduction

Football (soccer) is one of the most complex sports in the world, where players need technical, tactical, and physical skills to achieve a successful performance, and eventually to win a game [1]. A team's performance depends on the cooperative interactions between players that play at different playing positions [2]. For instance, the main role of midfielders is to organize the offense by proper ball control and passes, while the main duties of defenders are to win aerial duels and tackles or to perform interceptions of the balls passed to attackers [1, 3]. Understanding of these position-specific demands is crucial in the evaluation of players' achievement [4].

Players' duties (i.e., passes, shots, interceptions, tackles) are usually known as game performance indicators (GPIs) [3]. Essentially, GPIs are defined as a "selection and combination of variables that define some aspect of performance and that help achieve athletic success", and studies frequently have examined these characteristics and demands of individual roles within a football team framework [5]. Thus, Yi et al. used GPIs and investigated technical demands of different playing positions in the UEFA Champions League [1]. Further, Modric et al. identified associations between GPIs and running performance for specific playing positions of elite level football players [3], while Dellal et al. identified the positional demands from both technical and physical aspects in the French First League using the various GPIs [6]. Collectively, the results pointed to high applicability of GPIs in the evaluation of team- and position-specific-achievement.

Modern football requires high levels of endurance, speed, strength and coordination skills [7]. Therefore, players need to have well-developed physical fitness. Considering the fact that energy used by football players is mainly produced by aerobic metabolism [8, 9], it is important for players to have well-developed aerobic fitness (AF). Specifically, a proper level of AF allows players to maintain repetitive high-intensity actions within a football game, to accelerate the recovery process and to maintain their physical condition at an optimum level during the entire game and season [10].

To evaluate AF, maximal oxygen uptake (VO2max) and anaerobic threshold (AT) measures have commonly been used [11, 12]. In general, VO2max corresponds to the highest work rate at which oxygen can be taken up and utilized by the body during maximum exercise [13, 14], and in professional football players, it can vary from 55 to 65 ml kg^{-1} min^{-1} [8,15]. AT is defined as the highest exercise intensity at which the production and clearance of lactate is about the same [16]. It can be

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evaluated from blood lactate level changes (i.e., metabolic acidosis) or from noninvasive gas exchange measurements due to the nonlinear increase in carbon dioxide production and ventilation [11, 17, 18]. Although both VO2max and AT can be assessed indirectly through field tests, the most accurate measure is based on laboratory testing on a treadmill [15].

Taking into consideration differential game duties of players involved in different playing positions, previous studies have identified differences in AF between playing positions [19]. However, the results generally did not support the initial consideration of existing differences among playing positions in VO2max values between defenders, midfielders and forwards [10]. Furthermore, some studies tried to establish a relationship between AF measures with running performances (e.g., total distance covered and distance covered in different running speed) [20, 21], and even with football success (e.g., position on the table) [22]. In general, authors of these studies reported a significant relationship between VO2max obtained by field based tests, and distance covered during a game collectively evidencing the positive correlation of VO2max and football achievement [20, 21].

Interestingly, although GPI and AF are known to be important determinants of success in football, and these indicators are often investigated separately, to the best of our knowledge, no study thus far has observed a relationship between direct measures of AF and GPIs. We were of the opinion that investigating this issue will provide information about interrelationships that exist between these two sets of indicators, which could consequently improve the applicability of both AF and GPIs in football training or competitions. Therefore, the aim of this study was to identify possible associations that may exist between AF and GPIs in elite level football players according to their playing position. Additionally, knowing the lack of studies which evaluated the AF by direct laboratory measurement, we compared AF indices among football-specific playing positions.

2. Methods

2.1. Participants and design

The sixteen participants in this research were professional football players from Croatia (mean ± SD, age: 23.76 ± 2.64; body height: 181.62 ± 7.09 cm; body mass: 77.01 ± 6.34 kg) from a team that competed at the highest level (national championship). The players were observed over one competitive half-season (14 games), resulting in 82 game performances that were used as cases for this study. The players' performances were grouped according to their main playing position as defenders (n = 39), midfielders (n = 32) and forwards (n = 11). Team formation and playing positions are presented in Figure 1. We analyzed only those players who participated in the whole game. In the observed half-season, the team played seven home and seven away games, with three wins, eight draws and three losses. At the end of the observed half-season, the team ranked 6th of 10 teams that competed in the Croatian Football League. All the participants were fully informed about the nature of the study and signed an informed consent form agreeing to participate in the study. The study was approved by the Ethical Board of the University of Split, Faculty of Kinesiology (EBO: 2181-205-02-05-19-0020).

2.2. Procedures

Apart from age, body mass and height, the variables observed in this study were GPIs and AF.

The GPIs for each player were determined by the position-specific InStat index (InStat, Moscow, Russia). The InStat index is a unique parameter that provides an assessment of a player's game performance. It is created by an automatic algorithm that considers the player's contribution to the team's success, the significance of their actions, opponent's level and the level of the championship at which they play (i.e., the same performances in the European Champions League and some national-level first divisions will not be rated with the same values). The exact calculations are trademarked and known only to the manufacturer of the platform, but in general, the InStat index is calculated on the basis of a unique set of key parameters for each playing position (12–14 performance parameters depending on the position during the game). These key factors included in the calculation of the InStat index are position-specific and include tackling, aerial duels, set pieces in defense, interceptions (for central defenders); number of crosses, number of passes to the penalty area, pressing (for fullbacks); playmaking, number of key passes, finishing (for central midfielders); pressing, dribbling, finishing, counterattacking (for wingers); shooting, finishing, pressing, and dribbling (for forwards). The rating is created automatically, and to produce an InStat index for an individual athlete, athletes had to participate for a required minimum amount of time in a competition and complete a certain number of on-field actions (in this study, this issue was solved simply by including only those players who played the whole game). The weight of the action factors differs depending on the player's position. For example, grave mistakes made by the central defenders and their frequency affect the InStat index to a greater extent than those made by the forwards. The InStat Index values were collected during 14 games of the Croatian Football League 2018/2019 season, and higher numerical values indicate better football performance. The validity and applicability of the InStat index for professional football players has previously been demonstrated [3, 23].

Figure 1. Team formation with main and specific playing positions in soccer game.

The AF was determined by maximal oxygen uptake (VO2max), running speed at aerobic threshold (AeT), running speed at anaerobic threshold (AT), VO2max at anaerobic threshold, heart rate at anaerobic threshold, maximal heart rate, test running time, running time above AT and maximal running speed. Spiroergometric testing was conducted before the preseason and immediately after the off-season period using a progressive intensity and continuous effort treadmill protocol (Cosmos h/p, Nussdorf—Traunstein, Germany). All players performed a test after two light football adaptation sessions to minimize the possibility of injury and the effect of fatigue. On the testing day, the laboratory room temperature was 19–22 °C, and the relative humidity was approximately

50%. Just before the start of testing, players performed individual warm-ups consisting of 7 min of running at their own pace and 3 min of dynamic stretching. The test protocol started at 8 km/h with speed increments of 1 km/h every minute until they could no longer keep pace. A constant incline of 2% was applied. The players were instructed to run until voluntary exhaustion was reached and were given strong verbal encouragement throughout the test to elicit their best performance. Oxygen uptake and various cardiorespiratory measures were continuously recorded and monitored using a valid ($R2 = 0.97$; standard error of the estimate $= 2.30$ ml kg^{-1} min^{-1}) automated breath-by-breath metabolic system (Quark CPET, Cosmed, Rome, Italy) and averaged across 15-s epochs. The metabolic system was calibrated following manufacturer guidelines prior to each test. Heart rate was monitored using a monitor (Garmin HRM3—SS, Garmin Ltd, Olathe, KS, USA) positioned at the base of the sternum and measured at a frequency of 1 Hz. According to a previous study [15], VO2max was accepted when at least 3 of the following criteria were met: (1) the HR during the last minute exceeded 95% of the expected maximal HR predicted 220-age; (2) leveling off (plateau) of VO2max, despite an increase in treadmill speed, $VO2 < 150$ ml O2; (3) a respiratory gas exchange ratio ($VCO2 < VO2$) at or higher than 1.1 was reached; and (4) the subjects were no longer able to continue the running despite verbal encouragement. VO2max was expressed in relative values (ml kg^{-1} min^{-1}). According to a previous study [24], the AeT was defined as the first nonlinear increase in the ventilatory equivalent for oxygen without a simultaneous increase of the ventilatory equivalent for CO2, whereas AT was defined as the simultaneous nonlinear increases of both ventilatory equivalents according to previously described recommendations [17, 18]. Both AeT and AT were expressed in km/h.

2.3. Statistics

The normality of the distributions was confirmed by the Kolmogorov-Smirnov test, and the data are presented as the means ± standard deviations. Homogeneity was assessed by Levene's test. Multivariate differences among playing positions in AF indicators were analyzed by canonical discriminant analysis. Univariate differences in AF between playing positions were analyzed by one-way analysis of variance (ANOVA), with the Scheffe post hoc test. Effect size differences were established by ANOVA-derived partial eta squared (>0.02, small; > 0.13, medium; > 0.26, large; [25]). The ANOVA evidenced significant differences among playing positions in age (please see Results for more details). Therefore, for those variables where ANOVA identified significant differences among playing positions, analysis of covariance (ANCOVA) was additionally calculated with age of participants as confounding factor (e.g. covariate).

Pearson's correlation coefficients were calculated to identify the associations between AF and GPIs. Classification of the r coefficient was determined as previously suggested: $r \leq 0.35$ indicates a low or weak correlation, $r = 0.36$ to 0.67 indicates a modest or moderate correlation, $r = 0.68$ to 1.0 indicates a strong or high correlation, and $r > 0.90$ indicates a very high correlation [26]. Correlations were calculated for the total sample and stratified for playing positions. For all analyses, Statistica (Version 13; TIBCO Software, Palo Alto, CA, USA) was used. A significance level of $\alpha = .05$ was applied.

3. Results

Table 1 presents descriptive statistics and differences in AF measures between players in various playing positions in the game. Significant differences were evidenced for age, with forwards being oldest. Midfielders had the greater AeT (14.31 km/h) compared to defenders and forwards (13.41 and 12.81 km/h, respectively). Forwards had the lowest AT (15.45 km/h) compared to the midfielders and defenders (16.46 and 16 km/h, respectively) (significant post hoc differences when forwards were compared to the midfielders). Further, ANCOVA calculations controlled for age as covariate (note that playing positions differed significantly in age) revealed significant differences among playing positions in AF as well ($F\text{-test} = 16.08, 7.25$; both $p < 0.01$ for AeT and AT, respectively).

Discriminant canonical analysis demonstrated multivariate differences among playing positions in AF measures (Table 2). In the calculation of the discriminant function only variables that were not intercorrelated/derived from other variables (i.e. Vo2max at AT). Both discriminant roots reached statistical significance. The first one (Wilk's Lambda $= 0.18$, $p < 0.001$) explained differences between forwards and remaining two positions (midfielders and defenders). In short, midfielders and defenders outperformed forwards in all AF indices, especially AeT (correlation with discriminant root of 0.42), and maximal running speed (correlation of 0.27). The second discriminant root explained differences between midfielders and defenders (Wilk's Lambda $= 0.68$, $p < 0.001$) and evidenced midfielders being superior in AeT and

Table 1. Descriptive statistics (mean ± standard deviation) of aerobic performances, and differences among players in various playing positions in the game (F-test, η^2 – partial eta squared).

	Defenders (n = 39)	Midfielders (n = 32)	Forwards (n = 11)	F-test (p)	η^2
Age (years)	23.56 ± 2.04^{F}	22.78 ± 2.57^{F}	$27.36 \pm 1.75^{D,M}$	17.56 (0.01)	0.30
Body height (cm)	182.61 ± 8.69	180.47 ± 6.02	181.45 ± 0.52	0.80 (0.45)	0.02
Body mass (kg)	78.1 ± 7.17	74.62 ± 4.4^{F}	80.09 ± 6.09^{M}	4.5 (0.01)	0.01
InStat index	246.56 ± 28.61	254.9 ± 29.41	239.9 ± 43.18	1.16 (0.31)	0.03
VO2max (ml kg^{-1} min^{-1})	57.83 ± 1.38	57.71 ± 4.96	56.72 ± 3.65	0.44 (0.64)	0.01
AeT speed (km/h)	$13.41 \pm 0.67^{M,F}$	$14.31 \pm 0.89^{D,F}$	$12.18 \pm 1.40^{D,M}$	25.36 (0.01)	0.39
AT speed (km/h)	16 ± 0.76	16.46 ± 0.80^{F}	15.45 ± 0.93^{M}	7.25 (0.01)	0.15
Maximal HR (beat · min^{-1})	193.31 ± 7.15^{M}	188.34 ± 10.02^{D}	192.82 ± 6.54	3.3 (0.04)	0.08
Maximal running speed (km/h)	18.67 ± 0.70^{F}	18.63 ± 1.10^{F}	$17.45 \pm 0.93^{D,M}$	8.27 (0.01)	0.17
Test time (s)	660.69 ± 28.35	662.13 ± 68.56	629.27 ± 53.73	1.89 (0.16)	0.05
Vo2max at AT (ml kg^{-1} min^{-1})	53.59 ± 2.00^{F}	52.49 ± 3.90	50.74 ± 1.49^{D}	4.52 (0.01)	0.10
Vo2max at AT (%)	92.72 ± 3.19^{F}	91.08 ± 2.76	89.65 ± 3.33^{D}	5.34 (0.01)	0.12
HR at AT (beat · min^{-1})	185.26 ± 6.20^{M}	180.22 ± 10.45^{D}	182.82 ± 7.28	3.28 (0.04)	0.08
HR at AT (%)	95.96 ± 1.60^{F}	95.71 ± 1.74	94.43 ± 0.67^{D}	4.08 (0.02)	0.09
Time above AT (s)	134.15 ± 44.88	114.16 ± 38.26	132.91 ± 12.79	2.43 (0.09)	0.06

AeT – aerobic threshold; AT – anerobic threshold; HR – heart rate; D – significant post differences to defenders; M - significant post differences to midfielders; F - significant post differences to forwards.

Table 2. Multivariate differences in anthropometric and aerobic fitness variables among playing positions calculated by discriminant canonical analysis.

	Root 1	Root 2
Body height	-0.01	0.20
Body mass	-0.14	0.350
VO2max	0.06	0.037
AeT speed	0.42	-0.58
AT speed	0.21	-0.34
Maximal HR	-0.06	0.38
Maximal running speed	0.27	0.098
Test time	0.13	0.013
Can R	0.86	0.57
Wilks's Lambda	0.18	0.68
p	0.001	0.001
C: Midfielders	0.82	-0.78
C: Defenders	0.46	0.69
C: Forwards	-4.03	-0.18

Root – structure of the discriminant factor, Can R – canonical correlation, C – centroid of the observed group on the discriminant factor, AeT – aerobic threshold; AT – anerobic threshold; HR – heart rate; D – significant post differences to defenders.

AT (correlations with discriminant root of 0.58 and 0.34, respectively), while defenders were taller and heavier (correlations of 0.35 and 0.20, respectively). Correct classifications were obtained for 71% of midfielders', 87% of defenders', and 72% of forwards' performances (79% correctly classified in total).

Table 3 presents Pearson's correlations between AF measures and InStat Index values for players in various playing positions in the game. There were no significant correlations between any measure of AF and InStat Index values for all playing positions.

4. Discussion

This study highlighted two important findings. First, the values of the AeT and AT differ among playing positions, while VO2max was not found to be a good discriminator of AF among players playing at different playing positions. Second, no correlations were found between AF and InStat index values, which indicates that InStat index is not influenced by AF in studied players.

4.1. Differences in aerobic fitness among playing positions

The results of this study demonstrated differences in AeT and AT values among players at different positions. Midfielders had the highest AeT (14.31 km/h), followed by defenders (13.41 km/h) and forwards (12.81 km/h), which had the lowest value of AeT. In addition, midfielders have the highest AT values (16.46 km/h) compared to defenders and forwards (16 and 15.45 km/h, respectively). Considering to their demands in the football games, the results may be explained as follows.

The midfielders in this study consisted of players who played in the middle (e.g., central-midfielders) and by the side of the field (e.g., wide-midfielders). The central-midfielders are characterized by the greatest total distance covered during the game, and especially by the greatest distance covered at moderate speeds [3, 27]. These running speeds in football (13–16 km/h) correspond to the intensity of AeT [27]. Conversely, wide-midfielders are characterized by the greatest high-intensity (>19.8 km/h) distance covered during the football game [28, 29]. To achieve this large amount of high-intensity running, wide-midfielders must have a highly developed AT [30]. Specifically, a highly developed AT enables them to perform high-intensity work without continued blood lactate accumulation in the body. Consequently, it is evident that high AeT and AT are directly related to game duties of midfield players, which explains their superior results on these AF indicators.

In contrast, forwards had the lowest values of AeT and AT. One of the most important tactical roles of forwards is to keep the ball in possession in the central position; therefore, it is expected that forwards do not cover a large distance [3]. Additionally, it has been reported that forwards are actually undertrained in terms of sprint distance covered through weekly training sessions, which means that they do not experience large amounts of sprint distance in training sessions [31]. Taking into account the above discussed influence of ANAT on high-intensity distance covered (high-speed running and sprinting), it seems that forwards in their training methodology probably do not have enough training stimuli to enable them to develop their AT. Similarly, previous studies have reported that forwards' training drills are based on short-intensity efforts (high-intensity accelerations and decelerations + shooting) rather than sprinting [31]. All of these factors together (e.g., tactical roles in game and training style) probably resulted in a relatively low level of AF in forwards. However, regardless of the explained background, it is important to emphasize that low AF can significantly limit the football performance of forwards since sprint distance covered during the game has been demonstrated as a highly important determinant of overall game performance for forward players [3].

The average values of VO2max (ml kg^{-1} min^{-1}) were 57.83 ± 1.38 in defenders, 57.71 ± 4.96 in midfielders, and 56.72 ± 3.65 in forwards. These results are consistent with previous studies that reported that average VO2max values in elite football players were between 55 and 65 ml kg^{-1} min^{-1} [15,32]. However, it cannot be ignored that our players achieved results that are similar to those reported for 2nd division players [15], while it would be expected that their results will be closer to those reported in studies performed on 1st division players, which reported

Table 3. Pearson's correlations between measures of aerobic fitness and Instat Index between players in various playing positions in the game.

	Defenders (n = 39)	Midfielders (n = 32)	Forwards (n = 11)
VO2max (ml kg^{-1} min^{-1})	0.07 (p = 0.66)	-0.12 (p = 0.50)	-0.05 (p = 0.87)
AeT speed (km/h)	-0.10 (p = 0.56)	0.21 (p = 0.25)	0.01 (p = 0.96)
AT speed (km/h)	-0.01 (p = 0.97)	-0.16 (p = 0.38)	0.01 (p = 0.96)
Maximal HR (beat · min^{-1})	0.06 (p = 0.72)	0.02 (p = 0.92)	0.07 (p = 0.84)
Maximal running speed (km/h)	-0.07 (p = 0.69)	-0.09 (p = 0.60)	0.01 (p = 0.96)
Test time (s)	-0.05 (p = 0.77)	-0.08 (p = 0.64)	0.02 (p = 0.94)
Vo2max at AT (ml kg^{-1} min^{-1})	-0.22 (p = 0.18)	-0.21 (p = 0.25)	-0.02 (p = 0.95)
Vo2max at AT (%)	-0.30 (p = 0.06)	-0.15 (p = 0.40)	0.07 (p = 0.83)
HR at AT (beat · min^{-1})	0.15 (p = 0.35)	0.04 (p = 0.81)	0.06 (p = 0.85)
HR at AT (%)	0.18 (p = 0.28)	0.06 (p = 0.74)	-0.01 (p = 0.98)
Time above AT (s)	0.06 (p = 0.71)	0.06 (p = 0.75)	0.08 (p = 0.81)

VO2max - maximal oxygen uptake; AeT – aerobic threshold; AT – anerobic threshold; Vmax – maximal running speed at test; HR – heart rate.

average values of above 60 ml kg^{-1} min^{-1} [22,33]. The most likely reason for the relatively low level of AF may be found in the fact that the testing protocol was conducted at the beginning of the season, after 20 days off-season. At this particular moment, players were at their lowest training level, which resulted in relatively poor AF.

The lack of significant differences in VO2max are consistent with previous studies where authors frequently reported no differences in VO2max values between playing positions. Specifically, in a study with Saudi professional football players, the authors found no significant difference between defenders, midfielders, or forwards [19]. Similarly, a recent meta-analysis indicated the limited applicability of VO2max in differentiating playing positions in football (exclusive of goalkeepers) [10]. The AT is a better indicator of AF in predominantly aerobic events [8, 16, 34]. The explanation is mostly based on the metabolic demands of football and the physiological differences of AT and VO2 as indicators of AF.

In brief, the AT is associated with peripheral aerobic responses such as increases in capillary density and in the ability to transport lactate and H+ ions [35], whereas VO2max is essentially limited to central factors (e.g., cardiac output) [8, 13]. In more detail, VO2max is limited by the ability of the cardiorespiratory system to deliver oxygen to the exercising muscles, while running economy and utilization of VO2max (and not VO2max level itself) affect endurance performance [34]. This can be supported by studies that have been made to investigate the relationship between physiological variables related to aerobic fitness and running performances. For example, in a study by da Silva et al, VO2max was not associated with repeated sprint ability, which is one of the most important indicators of success in football [36, 37]. Meanwhile, in the same study, repeated sprint ability and AT were significantly correlated, indicating that AT should be considered as a more important indicator of AF in football than VO2max [37].

4.2. *Associations of aerobic fitness and game performance indicators*

We have found no association between AF and InStat. To the best of our knowledge, this is the first study that determined the studied relationships, and therefore, in the following text, the findings are primarily discussed from the aspect of the authors' expert knowledge of this issue. First, although AF is an important determinant of players' quality, the players with lower AF can still possess excellent technical-tactical abilities, which will ultimately result in high values of the InStat index during the game. Indeed, players can be very efficient in performing their football duties at their playing positions, regardless of their somewhat lower AF, while players with excellent AF could be limited in their technical-tactical abilities. Second, technical-tactical performances (observed herein using the InStat index) are significantly influenced by the playing experience [38]. In particular, older and more experienced players are certainly able to handle their football demands more efficiently, even with a possible deficit in their AF. However, applicability of these findings could be limited only to the players in similar level of competition such as Croatian first division.

Indeed, older and more experienced players tend to have a lower level of AF compared to younger and less experienced players, but regardless, they are usually the most important and most useful players in the team. This can be supported by the results of a recent study in which authors reported a clear loss of physical performance among players over 30 years compared to younger footballers [39] and highlighted an age-related decline in aerobic fitness, reporting significant 5% reductions of VO2max in players >30 years compared with younger players [40]. Accordingly, even our study noticed that the oldest players (e.g., forwards; significantly older than defenders and midfielders) had the lowest values of VO2max, AeT and AT (please see Table 1 for details). These findings could be indirectly confirmed through ANCOVA calculations of the position-differences in AeT, where age was controlled as covariate. In brief, results revealed significant differences among playing positions but with evident decrease of F-test value for differences in AeT (F-test = 25.36 and 16.08 for ANOVA and ANCOVA calculation, respectively).

Third, this study was conducted while observing players in the Croatian league, a physically less-demanding competition compared to the top-level leagues [3]. As a result, the lower physical demands of the games in the Croatian first division certainly allow players to perform technical and tactical actions efficiently irrespective of their AF level. Considering all of the above, it seems that AF does not affect the situational efficiency of players at different playing positions in the Croatian 1st Division, which consequently does not affect the InStat index. However, this must be investigated in detail in future research.

4.3. *Limitations and strengths*

The most important limitation of this study comes from the fact that data were collected from only one team, and only players who played entire games during one half-season were analyzed. Further, testing of AP was conducted after approximately 20 days of off-season, and the observed half-season lasted 20 weeks. As a result, it is possible that AP changed over the half-season due the training process. It must be taken into account that this issue directly affects results of association between AF and GPI.

This is the first study that observed elite-level football players and determined the association between AF obtained by a direct testing method and GPI. Second, this study analyzed several AF indicators, which has not been done so far.

5. Conclusion

The present study did not evidence a relationship between the AF and the InStat Index. This is likely because the InStat Index is a specific GPI that is primarily influenced by efficiency of technical-tactical elements of the football game. In other words, players can possess excellent technical and tactical skills that enable them proper situational efficacy, regardless of the eventual limits in their AF. Consequently, players can also have a high InStat Index irrespective of their AF. This is especially possible for older and more experienced players. In general, those players may not possess high levels of AF, while being highly efficient at their playing position due to their (i) excellent technical and tactical abilities and (ii) playing experience.

In addition, this study confirmed that VO2max is not a good discriminator of AF and AeT and AT are better indicators of AF in players at different playing positions. In particular, no differences were found in VO2max values among players at different playing positions in the game, while midfielders had the highest values of AeT and AT. Accordingly, we may conclude that the midfielders have the best developed AF, irrespective of nonsignificant differences among playing positions in VO2max.

The lowest levels of AeT and AT were observed in the forwards, showing the poorest level of AF. It is important to emphasize that less developed AF can limit forwards' overall performances during a football game. Accordingly, it is highly recommended to improve the AT of players playing in the front playing positions during the training process.

Declarations

Author contribution statement

T. Modric: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

S. Versic: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data, D. Sekulic: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Declaration of interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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